HISTORY OF ACALA COTTON VARIETIES BRED FOR SAN JOAQUIN VALLEY, CALIFORNIA

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PREFACE

This report traces the development of Acala cotton from 1906 to 1970 with special emphasis on the Acala varieties used for production in the San Joaquin Valley of California. I have made no attempt to trace the illustrious history of California cotton production, beginning with cotton grown around the Spanish Missions in the early 1800's.

This study begins with a search for cotton germ plasm in Mexico and Central America. Then, following the introduction of the original seed from Acala, Mexico, we will see how breeders and growers in Texas and Oklahoma handled the "Acala" previous to the shipment of some seed to California in 1919. In more detail, I have covered the development of Acala varieties in the San Joaquin Valley.

I hope this account of Acala varietal improvements by breeders and their research associates will be a helpful reference for agricultural students, instructors, and cotton research personnel. Cotton industry people should also gain a better understanding of the changes in Acala varieties that they have grown, ginned, marketed, and processed for more than 50 years.

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HISTORY OF ACALA COTTON VARIETIES BRED FOR SAN JOAQUIN VALLEY, CALIFORNIA

John H. Turner[1]

DISCOVERY OF THE ORIGINAL ACALA

Discovery of the Acala cotton *(Gossypium hirsutum* L.) seed resulted from a search made in tropical America for stocks resistant to the boll weevil. The first indication of weevil resistance was found in 1902 by Cook (*5*)[2] in eastern Guatemala, where cotton culture was regularly maintained in the presence of the boll weevil by the Kekchi Indians, a tribe related to the ancient Mayas. A search for boll weevils was made in a field of the small native cotton, but no weevils or infested buds were found, although weevils were present in large numbers on another kind of cotton only a few feet away.

In 1904, the Kekchi country was again visited to determine the causes of immunity in the native cotton. As a result of these investigations, it was found that several characteristics of the Kekchi variety afforded only partial protection against the boll weevil (*6*).

In June 1906, cotton explorations were extended to several other districts of Guatemala and southern Mexico. Many native cottons were observed during the expedition, but a single plant of upland cotton (*G. hirsutum* L.) at Ocosingo, in eastern Chiapas in southern Mexico, attracted special attention and was recognized at once as a new and interesting type. The important features were the upright plant growth and large, well-formed bolls. Green bolls were collected, but boll rot developed in transit, causing loss of seed viability.

In December 1906, G. N. Collins and C. B. Doyle of the USDA returned to southern Mexico to locate the superior type that had been recognized by Cook and Doyle at Ocosingo in June. A small patch of a desirable, large-bolled type of cotton was found on the outskirts of the town of Acala. A sample of the local seed was obtained from the owner of a primitive gin and was labeled "Acala" in subsequent experiments in Texas. These seeds served as the parent stock for development of all Acala varieties in the United States (*6*).

ACCLIMATIZATION OF ACALA IN TEXAS AND OKLAHOMA

This original seed was grown in Texas, south and west of San Antonio, between 1907 and 1911, where breeders made plant selections for better adaptation. The Acala stock showed a wide range of diversity, but most of the plants were fertile and productive. Some of the plants had the characteristics of the superior type of cotton first seen at Ocosingo with the upright habit, large bolls, dense fiber covering of seed, early maturity, and productiveness.

In 1909, an outstanding type was isolated from the nursery near San Antonio, and, in 1911, seed increased from this type was moved further north and grown near Waco, Tex. D. A. Saunders isolated three strains, designated as Nos. 1, 2, and 3. Nos. 1 and 2 were moved to Clarksville, Tex., and No. 3 was sent to C. N. Nunn in Oklahoma in 1914 to learn how Acala would perform further north (*7*). Nunn, Cook, and Saunders (*in* Ware, *36*) selected plants from this strain in 1914. In 1915, the two progeny rows, Nos. 5 and 8, were selected as the best. Nunn preferred No. 5, but Saunders preferred No. 8 because of its similarity to the original Acala in Texas. The No. 1 and No. 2 selected stock at Clarksville and the No. 8 returned from Oklahoma were classified as the Acala-8 type, and only the Acala-5 type was propagated by Nunn in Oklahoma.

The Texas program continued to develop the Acala-8 type until 1921 or 1922. Interest in the Acala seed stocks for production and breeding in the rainbelt States waned rapidly as the boll weevil infestations increased from 1910 to 1919. This insect forced cotton breeders and growers in the South to reject Acala and many other breeding stocks solely on the basis of indeterminate growth habit and late maturity. Breeders in the South and Southeast, however, are due a great deal of credit for the progress they made from 1915 to the mid-1930's in developing rapid fruiting, early maturing varieties that could withstand the ravages of the boll weevil.

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[2]Italic numbers in parentheses refer to Literature Cited, p. 22.

Acala seed from Clarksville was used by W. B. Camp in cotton variety trials in the San Joaquin and Sacramento Valleys of California (see table 1). According to Cook and Doyle (*9*), Camp was sent to the San Joaquin Valley in 1916 to explore the possibilities of growing Pima cotton, which was needed for war materials. The first commercial planting of Acala was made in 1919 on 8 acres near Bakersfield. The crop was profitable to the grower who sold eight bales at 47¢ per pound. Seed from this planting was saved. In 1920, 350 acres were planted in a neighboring district with this Acala seed, and a small quantity was sent to the U.S. Date Garden Station near Indio, Calif. These two plantings of the Acala-8 type cotton from Texas were the nucleus for all commercial Acala production in California for several years (see fig. 1).

The high yields obtained in the Indio area from 1920 to 1923 led to the formation of the Coachella Valley Grower's Association, whose purpose was to produce only Acala cotton seed in that small isolated valley of approximately 3,000 acres. The organization furnished Acala planting seed to Arizona, New Mexico, and California until the early 1930's (*22*).

In the San Joaquin Valley, the Acala acreage increased rapidly from 1921 to 1926. In the spring of 1922, the U.S. Cotton Research Station was established near Shafter. Camp and his associates continued variety testing on valley ranches, but increased breeding and other research efforts at Shafter. New lines of Acala were obtained from Indio, Texas, and other areas. These men also initiated irrigation and fertility experiments. Cooperative experiments with various University of California scientists were undertaken to develop cultural information for cotton production in this new area of growth (*4*).

TABLE 1. — *Yield of seed cotton in variety comparisons, San Joaquin Valley, 1918-19*

Location	Date planted	Variety	Yield per acre
			Pounds
		Acala	2,335
		Durango	2,327
Shafter	Apr. 22, 1918	Meade	1,989
		Yuma	2,350
		Pima	2,368
		Acala	2,180
Chico	Apr. 24, 1918	Durango	1,479
		Meade	1,459
		Pima	1,216
		Acala	1,396
		Durango	1,159
Arvin	Apr. 15, 1919	Lone Star	1,361
		Meade	698
		Gila	889
		Pima	1,185
		Acala	2,044
		Durango	2,002
Shafter	Apr. 15, 1919	Gila	1,505
		Pima	1,449
		Acala	3,120
McFarland	Apr. 10, 1919	Durango	2,796
		Lone Star	2,944
		Pima	2,973
		Acala	1,588
		Durango	1,490
Chico	Apr. 23, 1919	Lone Star	1,293
		Meade	1,228
		Gila	1,046
		Pima	1,260

Variety trials consisted mainly of comparisons between Acala, Mebane, Lone Star, and Durango cottons. The latter three varieties had been the popular varieties previously imported from Texas by growers throughout California. Most of the individual test plots were evidently single comparisons, regular Acala compared to one of the other varieties. In annual reports (on file at Shafter), yield comparisons were made in five to eight areas several times from 1920 to 1924. In 80 percent of these tests, Acala produced more cotton than either of the other varieties. Whenever Mebane, Lone Star, or Durango outranked Acala, it was only by a few pounds. Delfos, a Mississippi variety, did perform better than Acala in the Sacramento Valley.[3]

Other production and marketing factors accounted for the growers preference of Acala as much as the actual yield. Its ability to make more growth in cool spring weather than the other varieties, to have more erect plants at maturity, and its greater resistance to adverse climatic conditions were noted by several investigators and cotton growers (*9*). Acala fiber was also superior in staple length, which was a very important factor in establishing a market for western cotton.

Over 40 introduced varieties were studied by Camp and Herbert.[4] These represented the types being grown throughout the Cotton Belt. Grown over a number of years, some varieties showed considerable promise for specific traits, but none was consistently as high in yield as the locally maintained Acala. Small bolls and inferior fiber were the major drawbacks of these varieties.

One-Variety District

As early as 1911, Cook (*7*) was promoting the one-variety community concept. By the 1920's, numerous gin communities were established around this concept in the Southeast. Evidently, Cook viewed the San Joaquin Valley as a potential one-variety community for producing extra-long staple

[3]CAMP, W. B., and HERBERT, F. W. ANNUAL REPORT TO HEADQUARTERS. In Shafter Station files. 1925. [Typed.]

[4]See footnote 3.

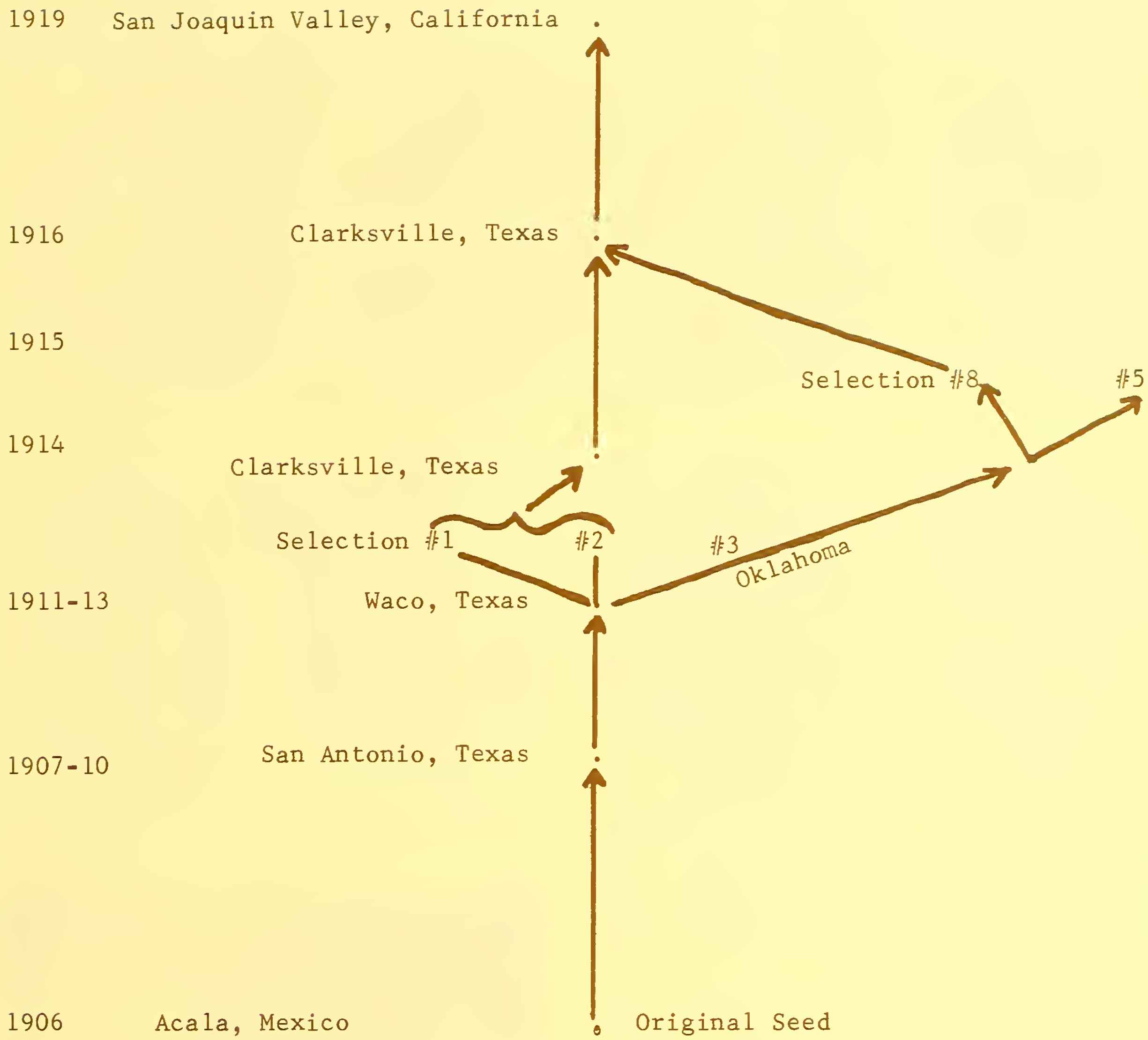

FIGURE 1.—Early years of Acala development, 1906-19.

(*G. barbadense*) when Camp was sent to the valley in 1916.

In 1918, Gilmore (*11*) stated, "There are certain economic considerations, however, that bear upon the production of cotton which ought to be mentioned. Among the most important of these are the desirability of adopting one type of cotton and continuing in the cultivation of that type. . . If cotton is to be grown as a regular crop in the valley it is important to understand that at the outset the necessity of adopting the variety best suited to the conditions of climate, soil, and market and grow that variety to the exclusion of all others. . . Under no circumstances whatever should short staple cotton be planted in the San Joaquin Valley.

"The San Joaquin Valley has the opportunity of producing a superior strain of cotton for which there is now a good market and for which there is every indication that a good market will continue. This is further emphasized since cotton responds to selection and good culture. . . It is not to be understood by what has been said that other varieties of cotton will not do as well (in the San Joaquin Valley). Our experiments show that they will, but what is the use of growing a variety that does not yield materially more and for which a much less price is obtained?"

Extra-long staple cotton (*G. barbadense*) production was shortlived in the San Joaquin Valley. The need for this type of cotton was greatly reduced after World War I, and the glowing prices that growers expected disappeared in 1920.

With no market for the extra-long staple cotton, growers began planting larger acreages of Acala. From only 3,500 acres of Acala in 1921, approximately 96,000 acres were in the San Joaquin Valley by 1925 and an additional 32,000 acres of Acala in other California valleys (*2*). The average

yield per acre for the San Joaquin Valley in 1925 was 393 pounds of lint, compared with 245 pounds of lint per acre in 1921.

In the spring of 1925, cotton ranchers and agricultural leaders from the Coachella Valley, with the help of some San Joaquin Valley agricultural leaders, convinced the State legislators to pass a One-Variety Law (*1*). This law made it "...prohibitive to grow any variety or species of cotton other than Acala in nine districts (counties); namely, Riverside, Kern, Kings, Tulare, Fresno, Madera, Merced, San Joaquin and Stanislaus." Imperial County did not choose to come into this program because growers there were planting large acreages of the Durango variety. In 1941, Riverside County asked to be released from the Law to grow Pima cotton, which was needed for World War fabrics.

Seed Organization Formed

In 1926, a seed distributor organization was formed in Kern County through the growers in the Farm Bureau. The purpose of this organization was to increase and distribute to all growers in the One-Variety District the Acala planting seed released by the USDA at the Shafter Station. This nonprofit organization, now known as the California Planting Cotton Seed Distributors, has functioned as a valuable and necessary link between the USDA breeding of Acala seed and the need by San Joaquin Valley growers for good planting seed of reliable performance. In other words, the organization has performed a dual role for the San Joaquin Valley, acting as a seed certifying agency and an organization for pure seed increase. Until 1968, they received Breeder's Seed from the U.S. Cotton Research Station and supervised the increase through three stages called white, purple, and green tag — the equivalent of foundation, registered, and certified classes, respectively. All growers were thus assured that an adequate supply of green tag seed could be obtained at their gin office. The tremendous value to growers in having such a system of pure seed multiplication of a good cotton was recognized in the early years of this organization (*3*, *27*).

SAN JOAQUIN VALLEY BREEDING

Early Years

The primary cotton breeding objective in California during the 1920's and early 1930's was the maintenance of the "Acala plant type." Nurseries were located at Shafter and Indio. Type selection for maintenance of seed stocks in one-variety communities was strongly advocated by Cook (*8*) who headed the USDA cotton research programs during that period (see figs. 2 and 3). Such a system had its limitations, but did assure breeders of preserving the major characteristic of a superior variety such as Acala and the availability of uniform seed stocks that performed reliably.

Acala, as grown in the early years, was derived from the acclimatization program and stabilization of a special type of Acala in Texas. Utilizing the type selection scheme in California, new lines came forth that were called "California Acala," "Shafter Acala," "Date Garden Acala," "Acala S5," and "Acala P12." Annual reports by Camp and McKeever (on file at Shafter) indicate that all of these California-developed Acala strains were descendants of Texas stocks of the Acala-8 type. Before McKeever's transfer to Indio from Clarksville, Tex., in 1921, a shipment of four lines were made for planting progeny rows at Indio. These were Oklahoma 8-1-1-1-2, 8-1-1-1-3, P12-13-5-1, and P12-19-1-3. In 1923, the Oklahoma 8-1-1-1-3 was turned over to Camp at Shafter for use in the San Joaquin Valley breeding program. The Acala S5 was a selection from Oklahoma 8-1-1-1-3, but was different in fiber properties. Camp and his associates soon found S5 fiber was too long and fine for satisfactory ginning (see table 2). Reselections from S5 gave rise to Acala S5-4-1 that was earlier

FIGURE 2.—Typical Acala plant selection, November 10, 1924.

FIGURE 3.—Normal and abnormal bolls of Acala-8 type (1924).

TABLE 2. — *Summary of 1924-26 spinning study of Shafter cottons*[1]
[SM = Strict Middling, M = Middling]

Property of test cotton	S-1	S-2	S-5	Broad Leaf	Okra Leaf
Grade	SM	SM	M	SM	SM
Length of staple (inches)	1-1/16	+1-3/16	1-5/16	+1-1/16	1-1/16
Total visible waste (percent)	7.91	6.86	9.46	6.61	7.15
Strength of yarn (pounds):					
50's	36.9	46.6	43.6	39.6	39.1
60's	27.5	35.8	33.6	28.5	27.5
Index of quality of yarn:					
50's	117	134	119	116	112
60's	97	124	113	101	97
Number of ends breaking on spinning frame per 100 spindles per hour:					
50's	3.5	2.7	1.4	0.8	8.0
60's	8.8	2.5	0.5	11.0	21.4

[1]Considering the manufacturing properties, that is, waste, number of broken ends on spinning, strength of yarn, average deviation, and extreme variation in break and size, the varieties rank as follows: S-5, S-2, Broad Leaf, S-1, Okra Leaf.

maturing. Also, the shorter fiber and plant features were more in line with the regular Acala being grown. Several hundred acres of S5-4-1 were grown in 1928, but it was withdrawn from the program by 1930 because of higher yields obtained in test plots from Acala P lines (see fig. 4).

Evidently, the domestic textile mills were well pleased with the San Joaquin Acala cotton in the 1920's. Records at the U.S. Cotton Research Station indicate that the mills were quite cooperative in running spinning trials with Acala strains. The following statement regarding the marketing ad-

vantage of Acala cotton appeared in a USDA Circular, dated November 1927 (*9*): "Acala cotton has found a ready market, and no defects or difficulties in using the fiber have been reported by manufacturers." Spinning tests conducted by Willis[5] verified the quality of Acala varieties as equal to or superior to most of the rainbelt varieties tested. Because more than 50 percent of the rainbelt area was growing varieties with staple length under fifteen-sixteenths of an inch, it is easy to see why the textile mills bought, without hesitation, western Acala cotton that stapled 1 1/16 to 1 3/16 inches. Furthermore, the western leaders had begun to establish their crop as a "uniform commodity," grown from a reliable Acala seed stock (*16*).

In the early 1930's, lines derived from Acala P12 progenies from the Indio Nursery were used in the San Joaquin Valley. Evidently, these lines produced more cotton than former selections from the Oklahoma 8-1-1-1-3. References in the files at Shafter emphasize the superb hand-picking feature of Acala P12. It appears, from records at Shafter,

[5] WILLIS. H. H. REPORTS ON SPINNING TESTS OF COTTON VARIETIES. 1924-26 SUMMARY. U.S. Dept. Agr. 12 pp. [Mimeographed.]

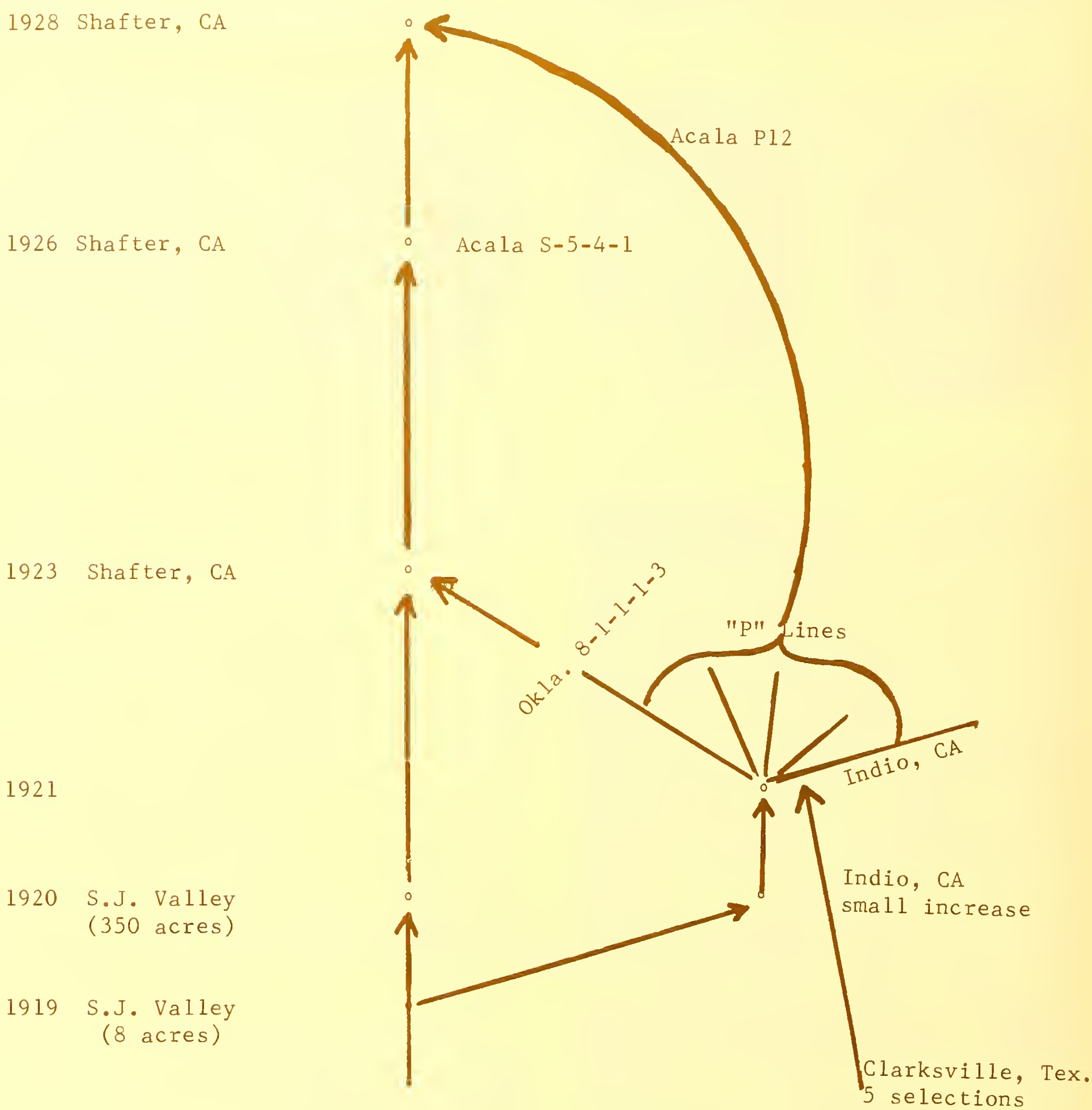

FIGURE 4.—Acala lines in California (1919-28).

that P7, P18, and P21, selected at Shafter from P12, made up the seed releases from 1932-39.

Performance data on Shafter Acala, Acala S5, and the Acala "P" lines are not available, although annual reports quote certain advantages for each successive release from 1925 to 1938. Cotton breeders of that era were more intent upon refining their product than in documentation of their accomplishments. It is evident, nevertheless, that progress was made within Acala strains for agronomic adaptation. Yield of lint per acre in the San Joaquin Valley rose from 245 pounds in 1921, to 495 pounds in 1930, to 657 pounds in 1939 on 2,500, 238,200, and 317,466 acres, respectively.

Changing Needs Affect Breeding Goals

In the 1930's, two new problems commanded the attention of the breeders and other cotton scientists in the San Joaquin Valley — verticillium wilt and fiber quality.

Verticillium wilt (*Verticillium albo-atrum*), a disease incited by a soil-borne fungus, was first identified by Shapovalov and Rudolph (*29*). Herbert and Hubbard (*15*) stated that this disease was first reported on cotton in a field near Wasco, Calif., in 1927. By 1930, cotton at numerous valley sites was found to be infected with the fungus. Numerous varieties were studied at Shafter and Wasco in 1930, but only the Pima (*G. barbadense*) showed any resistance. Hubbard, Herbert, and McKeever made selections for wilt tolerance in a number of varieties in 1931 and 1932. In 1934, George Harrison became head of the breeding program and cooperated with B. A. Rudolph, pathologist from the University of California, in an all-out effort to identify genetic differences for wilt tolerance (*12*). Wilt tolerance was found in certain strains of Cook, Mexican Big Boll, Kekchi, Tuxtla, and Mississippi Delfos (called Missdel in the California program) varieties. Field techniques for inoculation and wilt evaluation were developed during the late 1930's (see fig. 5).

Fiber quality, which was difficult for breeders to measure objectively before 1937, began to receive attention as new instruments were developed for accurately measuring fiber properties. Fiber strength and fineness as well as length and length uniformity were found to be related to spinning performance and yarn quality. As volume of western cotton increased, the domestic textile industry branded the fiber from Acala varieties grown under irrigation as "soft" and inferior to delta-grown cotton of the same length. Although the per-acre yield in the San Joaquin Valley had surpassed that of rainbelt areas, the situation in the domestic market was disturbing. Buyers were paying $10 to $15 per bale less for cotton from the San Joaquin Valley than for rainbelt cotton of the same staple length in the late 1930's and in the 1940's.

Acala P18C and Acala 4-42

George Harrison and his associates developed Acala P18C and Acala 4-42 from 1934 to 1949. The previous California Acalas were derived from plant-to-row breeding nurseries, but open-pollinated seed had been used for both the progeny rows in the following year's nursery and the bulk of seed for increase and valley distribution. Harrison initiated an inbreeding procedure in 1934. Several hundred plants were selected each year in early July. On a daily basis, he and his associates visited these preliminary selections in the early morning before the flowers opened. By wrapping the flower bud with a wired tab to prevent the petals from opening, all the seed from tagged bolls was self-pollinated (see fig. 6).

After several years of saving only self-pollinated seed for propagating the progenies, Harrison identified three distinct strains of P18, which he designated as P18A, P18B, and P18C (*13*). Strain A was rank growing and late maturing; strain B was less productive and had brittle stalks. P18C had a more desirable plant type, was less attractive to lygus bugs, and spinning tests indicated it spun smoother, less neppy yarn (see table 3). This strain was increased for release in 1939 and became the standard variety for the San Joaquin Valley from 1944 to 1948. The Acala P18C did not solve either the wilt problem or the market preference, but it was more popular with the growers (see fig. 7).

Self-pollinated seed from the best plants in the best progeny rows was harvested each fall, and gin and fiber laboratory data were obtained. These selected plants of Acala P18C usually came from 12 to 18 progeny rows. After selections were chosen each winter to provide seed for the next year's nursery, seed from the remaining selections was bulked to plant the first stage of increase (Breeder's Seed).

In addition to using the Acala strains on hand at Shafter, Harrison introduced seed stocks from New Mexico, Arizona, and Mississippi. He and his associate, S. C. McMichael, were intent upon developing wilt tolerance and higher quality fiber for use in the San Joaquin Valley. In an effort to transfer high wilt tolerance and high tensile strength into the adapted Acala strains, several hybrid combinations were made. The major wilt-tolerant stocks used were Cook, Missdel, and Kekchi within the *G. hirsutum* species, and Pima for an interspecies cross. For superior fiber properties, two introductions were used—an Acala x Hopi cross made by Peebles and Kearney in Arizona, and a newly released New Mexico strain, Acala 1517.

Staten has recently published a thorough account of Acala 1517 breeding in New Mexico (*30*). A simple sketch of its pedigree in figure 8, reveals that the origin of this cotton is different from either the Acala-8 or Acala-5 type. Acala 1517 traces back to a plant selection No. 9 made by Young in 1919 at

FIGURE 5.—B.A. Rudolph and assistants inoculating plants for Verticillium wilt in Shafter Breeding Nursery (1939).

FIGURE 6.—Self-pollination technique (wired tag identifies self-pollinated bolts at harvest.

TABLE 3. — *Classification and spinning test results of a series of cotton grown at Shafter, Calif., during 1940*

Variety	Spinning test data			
	Staple length	Picker and card waste	Yarn strength 22 counts	Yarn appearance[1] 22 counts
	Inches	*Percent*	*Pounds*	*Grade*
Acala P18A	1-1/32	9.18	103.8	B+
Acala P18B	1-1/32	8.59	98.5	B+
Acala P18C	1-1/32	9.08	95.0	A-
Acala 1517	1-1/16	9.47	123.2	A-
Acala S5	1-1/16	9.22	121.5	B
Stoneville 5	31/32	8.23	97.4	A-

[1]In accordance with USDA Agricultural Marketing Service Cotton Yarn Appearance Standards.

A=Excellent, A-=Very Good, B+=Good, B=Acceptable, B-=Poor.

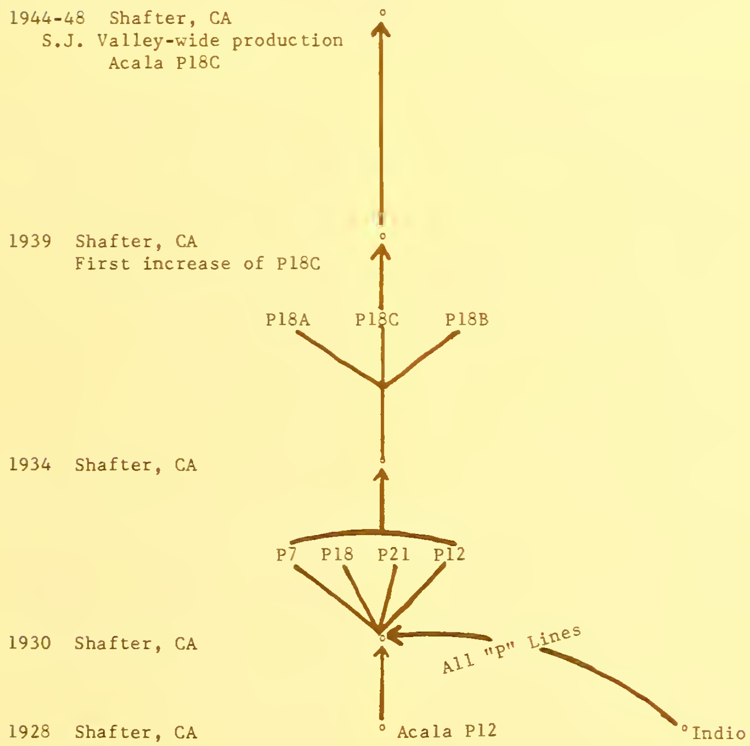

FIGURE 7.—Pedigree of Acala P18C, 1928-48.

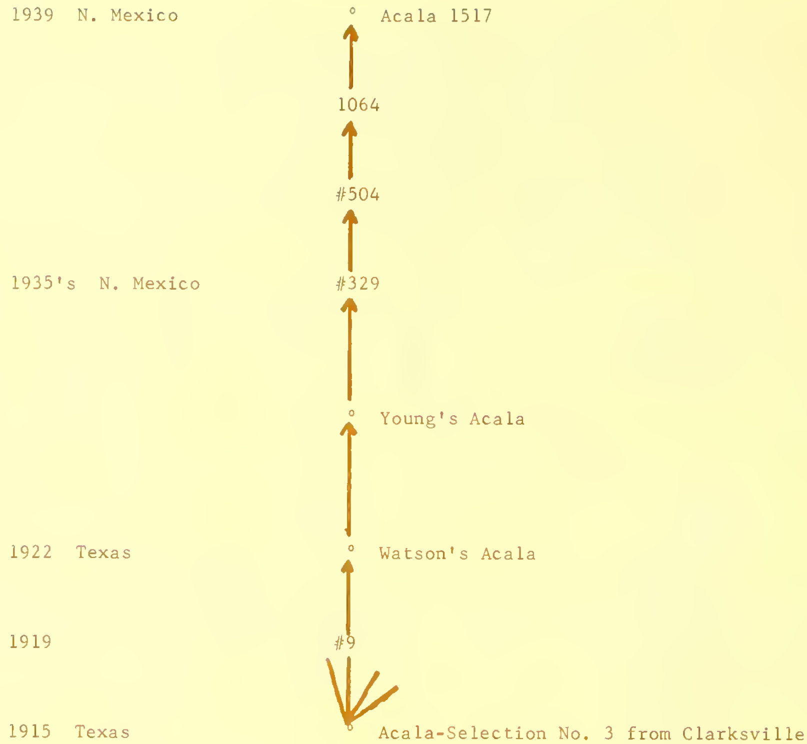

FIGURE 8.—Acala 1517 background sketch, 1915-39.

Italy, Tex. Progenies and increase plantings from No. 9 were called Watson's Improved Acala. Ramey (*28*) also reviewed the background of Acala and other varieties in a recent presentation.

Acala 1517, as first grown in a variety trial at Shafter in 1939, was noted to be in a heterozygous stage for several plant traits. This variability, equivalent to a hybrid "swarm," presented the breeders an opportunity for selecting more desirable combinations of agronomic and fiber traits. Ten plants were selected from the plot for use in the breeding nursery. Fiber laboratory data in 1941 revealed the progenies from plant No. 4 of 1939 had superior fiber properties.[6] A series of 1942 progeny rows that trace back to this plant were outstanding for production, maturity, and fiber quality in comparison with the standard variety, Acala P18C. A bulk of self-pollinated seed from these progenies was used for a small increase plot in 1943, designated as 4-42 (see fig. 9).

No yield advantage was claimed for 4-42 over that of P18C. The 4-42 was earlier to begin fruiting, somewhat shorter in height, and more stormproof; however, its greatest difference was in fiber quality. Fiber and spinning tests indicated that 4-42 was 20 percent stronger and produced 42 percent fewer neps than did Acala P18C (*14*) (table 4).

The much sought-for quality advancement was clearly present in this new variety, and both growers and processors were anxious to make a change. Hence, sufficient seed was made available to plant the entire San Joaquin Valley to Acala 4-42 in 1949. For several years, however, a number of growers claimed they made more cotton growing P18C and had less wilt damage. It was a remarkable achievement, when viewed in retrospect — to change thousands of acres from one variety to another, suddenly, without valleywide yield data to support the decision. Only the desperate need for better fiber made it possible. Within a few years, the textile industry recognized the superior quality and began to pay more for San Joaquin Valley cotton than for rainbelt cotton.

Lewis and Kerr[7], using nationwide variety testing data, have emphasized that components of cotton fiber quality are influenced by variety, environment, cultural practices, harvesting, and ginning. As pointed out by Kerr (*17*) in 1964, the cooler valleys of the Far West appear to have a different "fiber property potential" than the rainbelt regions, and it is highly desirable for breeders to continue developing varieties up to the limits of the quality potential.

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[6] HARRISON, G. J. SOME FACTS CONCERNING ACALA 4-42. Talk presented to Ariz. Cotton Assoc., Los Angeles, April 9, 1949. [Typed.]

[7] LEWIS, C. F., and KERR T. INFLUENCE OF VARIETY ENVIRONMENT ON COTTON QUALITY. Paper prepared for Extension Specialists Cotton Quality Conf., Greenville, S.C. May 2-4, 1967. [Mimeographed.]

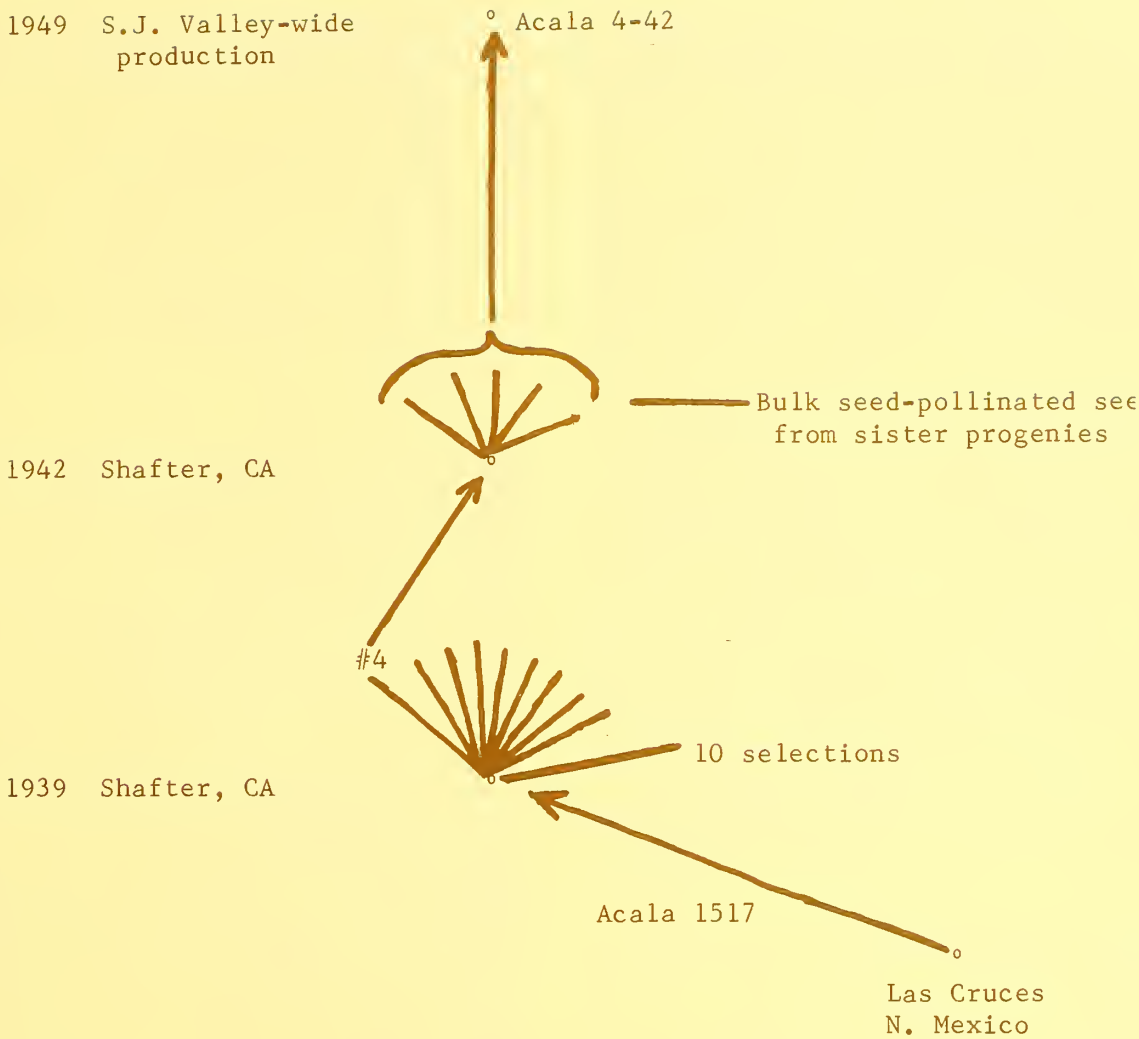

FIGURE 9.—Pedigree sketch of Acala 4-42, 1939-49.

TABLE 4. — *Comparison of California Acala P18C with Acala 4-42 (1944-47)*

Crop year	Acala strain	Staple length	Tensile strength	Micronaire fineness	Waste	Skein	Strength	Yarn appearance grade		Neps/ 100 in² card web
		Inches	*1,000 pounds*		*Percent*	*22's*	*36's*	*22's*	*36's*	
1944	P18C	1-1/32	70	4.6	6.21	109.1	57.4	B+	B	13
	4-42	1-1/16	88	4.2	5.20	137.3	73.3	B+	B+	12
1945	P18C	1-1/16	68	4.1	7.40	114.0	60.0	B	C+	14
	4-42	1-3/32	82	4.4	5.50	130.0	71.0	B+	B	12
1946	P18C	1-1/32	61		6.62	111.0	59.2	B+	C+	12
	4-42	1-1/16	78		6.09	132.9	72.9	B+	B	7
1947	P18C		66		6.73	112.0	58.9			13
	4-42		83		5.29	132.1	73.1			10

From a marketing standpoint, such cotton varieties as Acala 4-42 and 1517 need to be grown apart from other varieties (table 5) because the superior fiber properties and spinning quality of these cottons cannot be detected by the merchant or shipper by grade and staple classification.

The original release of Acala 4-42 displayed no improvement for wilt tolerance over the P18C; but, in a breeding program such as this, the breeder has on hand the seed to be used some 4 to 5 years later by the growers. Selection pressure continued from the 1942 selections, and, by 1947, considerable variability for wilt tolerance and other traits appeared in the 4-42 material. Between 1947 and 1950, Harrison was able to identify 12 sib lines having distinct phenotypic differences. The breeding nursery records at Shafter show that these sibs were all derived from two plants (Nos. 4-8 and 4-25) in a 1946 progeny row. This row had been planted to a Missdel x Acala progeny in 1945. It was also noted that plant 4-25 was not self-pollinated in 1946, but because of its excellent appearance on heavily-infested soil adjacent to a wilt-tolerant (MxA) x Acala 29 progeny, the seed was saved. Wilt tolerance was gained in the progenies of 4-25 but not in 4-8 progenies. The 4-25 phase of 4-42 was likely an outcross to MxA x A-29 or a volunteering plant from the 1945 row of MxA. At any rate, Harrison was able to establish eight highly wilt-tolerant sibs (called families) of this variety that became the base for the 1950 seed increase of the variety from which growers reaped the benefits beginning in 1954 (see table 6).

TABLE 5—*Kern County yield trial, 1948 (2 replicates)*

Yield, fiber, and spinning quality	Acala P18C	Acala 1517	Stoneville 2B	Acala 4-42
Yield (pounds lint/acre)	809	715	800	802
Fiber length:				
UHM (inches)	1.06	1.12	1.04	1.10
UR (percent)	79	80	80	87
Fiber strength:				
Pressley	70	97	80	88
Finess:				
Micronaire	4.6	4.2	4.7	4.2
Manufacturing waste:				
Picker and card (percent)	6.21	6.35	6.16	5.20
Neps/100 in^2 of card web	13	17	10	12
Carded yarn strength:				
22's (pounds)	109.1	145.2	111.6	137.3
36's (pounds)	57.4	80.1	58.7	73.3

Breeding Objectives Reappraised

In 1953, when the author became head of the California breeding program, it seemed appropriate to take an indepth look at future needs. Extension service personnel, ginners, merchants, and leading growers were most helpful. Their advice and personal observations made of the 1953 crop, indicated that mechanization and water management were factors fully as important as breeding to the future progress of cotton production in the San Joaquin Valley. An industry advisory committee to the total research effort at Shafter was organized. Following a number of discussions with the industry and the research staff, it was decided that earlier maturity should be a priority goal of the breeding program, but that such an effort should not be accompanied by relaxation of breeding for fiber quality or wilt tolerance.

The author initiated valleywide performance trials with several Acala strains in 1953. Testing was expanded in 1954 to compare the "models" (year of valleywide use) of 4-42 seed and family lines making up Acala 4-42. This testing was further expanded in 1955 to include more locations and newer strains from the breeding nurseries. Screening nurseries — to determine what varieties display the most earliness — were also planted at three locations. The breeding methods that Harrison had used in the nursery were continued. As data accumulated from valley tests, however, the particular seed to be used for breeders seed was chosen largely on the basis of valleywide performance of the 4-42 family components (*31*) rather than the amount of self-pollinated seed available.

Even though Acala 4-42 did show its first flowers earlier than P18C and gave more early season blooms, it was less efficient in the retention of flowers during the peak bloom period than many new lines. A large number of flowers, however, were retained by 4-42 from the last half of the 65-day bloom period. More than 60 percent of the valley crop was machine picked in 1953. It was inevitable that all valley cotton would soon be harvested by machine, which posed an added problem of damaging fiber and also revealed the need for early maturity. Engineers found that at least three-fourths of the bolls should be open before using the picking machine. The dependence of Acala 4-42 upon a heavy set of late season blooms did not allow an early machine harvest without sacrificing yield and damaging the fiber. Earliness, as defined in this program, was to be measured by the earliest date in the fall that cotton could be harvested by machines efficiently.

The breeding efforts were therefore divided into two distinct areas: (*1*) The improvements that might be accomplished within the Acala 4-42 material; and (*2*) the development of new strains of cotton that could possibly meet some of the objectives more fully than the 4-42.

Improving the Acala 4-42 Variety

The breeding and testing procedures used to improve the Acala 4-42 variety were discussed at length by the author (*31*) for the period 1953 to

TABLE 6—*1954 variety test, conducted at 5 locations, showing yield in bales per acre*

Variety	Shafter	Visalia	Chowchilla	Firebaugh	Corcoran	Average
Cal 4-42	[1]2.68	[1]2.67	[1]2.42	[1]2.71	2.89	2.67
Cal P-18C	2.21	2.25	1.88	2.13	2.86	2.27
N. Mex. 1517C	2.31	2.19	2.34	2.14	2.79	2.35
Ariz. 44	2.39	2.38	1.93	2.32	[1]3.11	2.43
Least Significant Difference: 5 percent	0.17	0.22	0.16	0.22	0.14	——

[1]Highest yield in each test.

1962. Variability within and between the eight major families of Acala 4-42 was sufficient to make several improvements. The first highly wilt-tolerant model grown valleywide in 1954 had a lower lint percentage than previous 4-42 models, which caused confusion among ginners and tenseness in grower-ginner relationships. Selection pressure that had been applied to improve this trait was fruitful, and the original high lint percentage was restored in the 1957 and later models of planting seed.

Fiber length was the next problem. During 1957-61, merchants claimed breeders had lowered the staple length 1/16 to 1/8 inch. Actually, our research data indicated a possible drop of only one sixty-fourth of an inch and that lint cleaners added to gins in those years diminished the fiber length by one-thirty-second of an inch or more. Nevertheless, a special effort was made in the breeding nursery beginning in 1958, to increase fiber length and length uniformity. This selection pressure was concentrated on only five important family lines. Longer fiber, together with all the other desirable features, was attained by 1961 in newer progenies of families 77, 176, and 132. A composite of these three was increased and reached the general grower as the 1964 model (see table 7). The improvement for quality from 1958 to 1964 was noted by the merchants and textile industry (*10*). Prices received by the San Joaquin Valley growers in the mid-1960's ranged from $15 to $35 per bale above Mississippi cotton.

By 1961, further advances in the breeding nursery, did not appear likely within the Acala 4-42 families. Thus, we concluded 15 years of intensive inbreeding and established a maintenance program for the three major families of Acala 4-42. This maintenance was accomplished by growing several rows of each family in the nursery and self-pollinating some flowers on each plant. A mass harvest of all selfed bolls constituted the increase lot for the family each fall. A reserve seed stock for each family was used to supply the yearly rows in the wilt nursery until Acala 4-42 could be replaced by a newer variety (see fig. 10).

TABLE 7. — *Comparison of 1961 and 1964 models of Acala 4-42,*[1] *3-year average*

Model of planting seed	Lint pounds per acre	Fiber and spinning data, Knoxville Lab. 2.5 span	U.I.	Micronaire	Yarn strength 22's
1961	997	1.09	46	3.9	136
1964	1,026	1.13	46	3.9	139

[1]1961 model seed was derived from 1956 breeding nursery progenies of families 77, 132, and 176. 1964 model seed was derived from 1959 breeding nursery progenies of families 77, 132, and 176, which were from longer fibered selections of 1958.

Development of New Acala Strains

In 1953 and 1954, the type of early maturity needed was best displayed by strains and varieties introduced from the southeast (see fig. 11). All Acala strains shed a high percentage of midseason blooms and, therefore, were dependent upon bloom retention from the last half of the 65-day bloom period to produce high yields (*32*). Of course, the regular southeastern varieties were ill-adapted to western culture and produced inferior fiber. As reported by Ware in 1950 (*37*), breeders across the belt were aware that the two groups of cotton were so diverse in many traits that they were considered as two distinct biotypes within the *G. hirsutum* species. From 1920 until the 1950's, it was rare to find a breeder who was interested in bringing these types together through hybridization.

Hybrids were made from 1953 to 1955 between special breeding lines from the southeast (with higher quality than standard varieties) and various Acala strains (see fig. 12). Another approach, which had been started by the author in Georgia, was also pursued — that of crossing early maturing, productive strains from Georgia onto the extra quality Hopi-Acala strains from Shafter.[8] This approach had one recognizable fallacy from the outset — that of the high wilt susceptibility of both parents.

Many disappointments were encountered in this new breeding endeavor from 1954 to 1960. For example, a number of F3 and F4 progenies with

[8]TURNER, J. H. UPLAND COTTON BREEDING FOR THE COASTAL PLAIN AREA OF GEORGIA. Coastal Plain Expt. Sta. Tech. Mimeo Paper. 42 pp. 1952. [Mimeographed.]

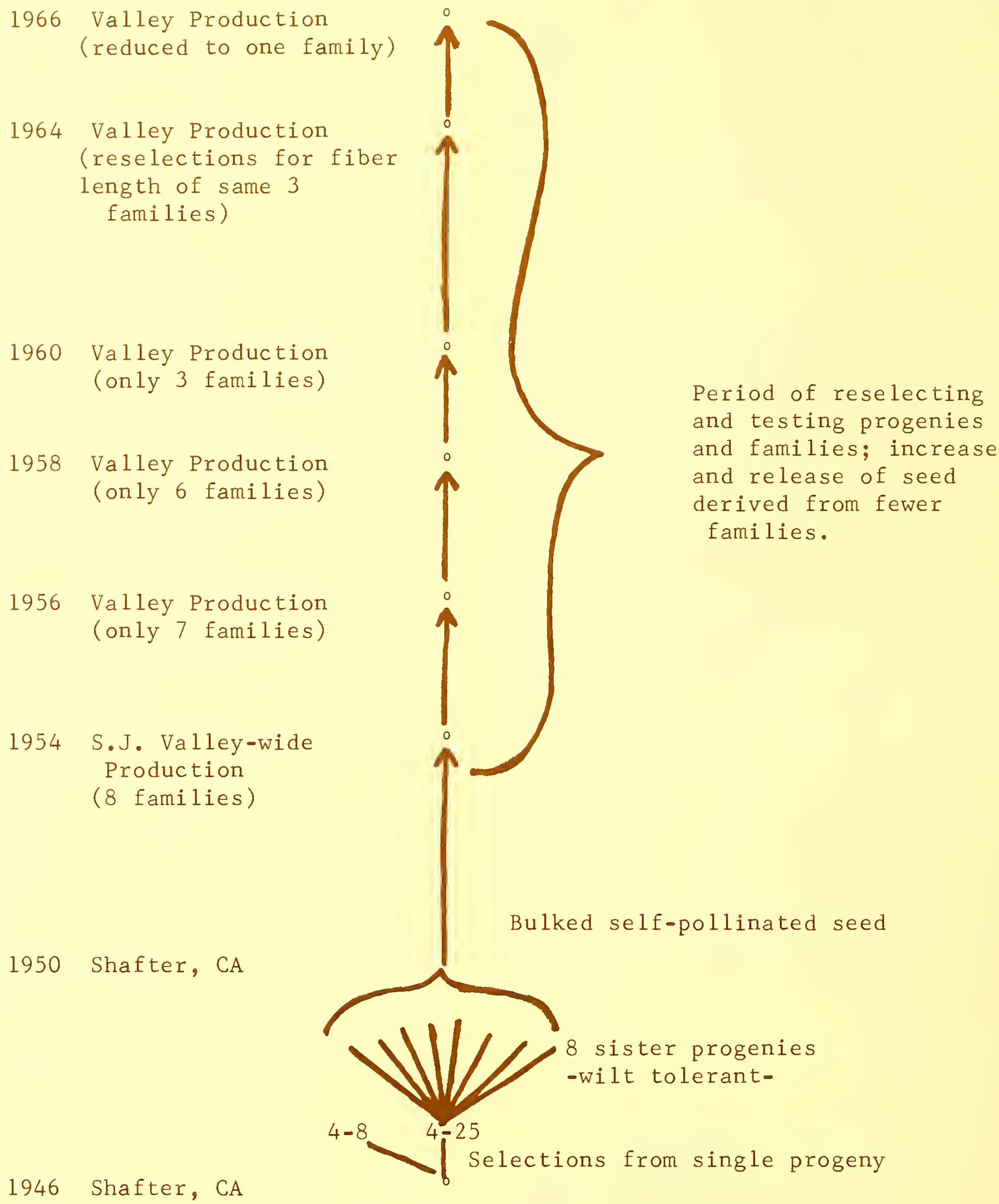

FIGURE 10.—Sketch of changes within Acala 4-42, 1950-66.

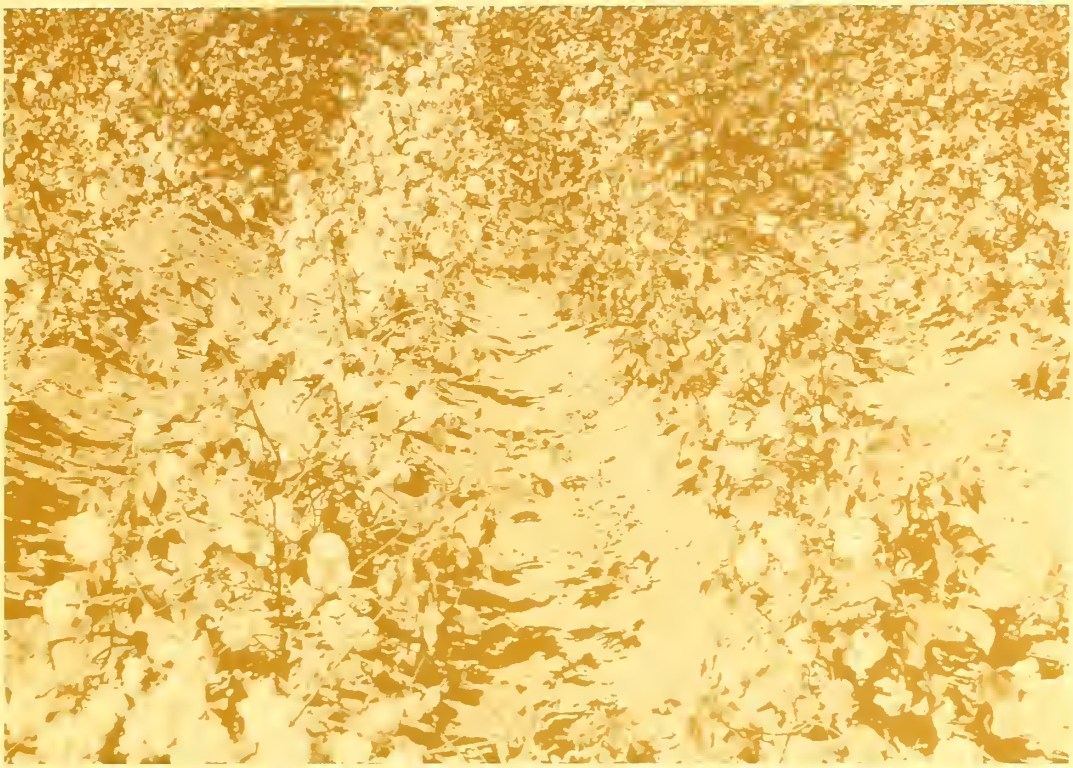

FIGURE 11.—Early Fluff adjacent to Acala 4-42 (right) in 1954.

FIGURE 12.—A51 (Shafter line) crossed with THEF (Georgia line) in 1953.

earliness and productivity were derived from Early Fluff x Hopi Acala 46-124 crosses. The fiber properties approached the Acala 4-42 standard, but by 1955 they were found to be highly susceptible to Verticillium wilt. These lines were transferred to Brawley, Calif., for potential use outside the wilt area and were used in backcrossing to several wilt tolerant Acala strains. Other "east-west" crosses provided segregates that could withstand moderate wilt conditions, but in most cases earlier maturity and/or fiber properties were sacrificed. When selective pressure in the F2 to F4 generations was primarily for early maturity, poor taproots were present. This resulted in a higher water requirement. Frequent irrigation, in turn, accelerated Verticillium wilt damage in late summer. Furthermore, attempts to recapture the desired tolerance to wilt resulted in late-maturing progenies that would defeat our early harvest objective.

Cooperative studies by Walhood and Stockton[9] revealed the differences in root system and fruiting-vegetative relationships among breeding stocks. Only AHA 6-1-5 and THEF had as extensive a taproot as did 4-42. Finally, in 1959, one significant advance was made in the stabilization of AXTE-1. This strain was 10 to 15 days earlier maturing than Acala 4-42, had a much higher bloom retention from midseason fruit, and was an excellent plant type for cultural management (fig. 13). AXTE-1 was derived from a cross made in 1953 between Acala 51 and THEF. This cross brought together widely different plant and fiber types. The A51 descended from the McMichael and Harrison crosses of (Missdel x Acala P18C) x Acala 29. The THEF was from a F4 line from the third backcross of Early Fluff onto the triple hybrid line 456-18 from Kerr in North Carolina. The F6 progenies in 1958 indicated that wilt tolerance and fiber data were approximately equal to 4-42 (*32*).

Again, disappointment was in store. AxTE-1 was entered in valleywide testing. In these experiments, the early maturity and yield were decidedly better than 4-42. Although wilt symptoms were more evident in AxTE-1 than in 4-42 by September, higher yields were obtained with AxTE-1. Yet, when fiber in larger quantities of replicated samples was submitted for spinning, it was found to be approximately 5 percent lower in yarn strength. Special fiber and spinning studies were conducted to determine the cause of the lowered performance of AxTE-1 and a slightly lower length uniformity was found to be the major flaw. Because the AxTE-1 was such a desirable agronomic type, two avenues were pursued to overcome this spinning deficiency: (1) Composite experimental strains, using AxTE-1 as a common component, were grown in yield trials, and bale lots were used for special spinning studies (*34*). In general, this did not seem to offer a totally satisfactory solution for meeting the spinning requirements for high-quality cotton. Furthermore, the composite strains were too much of an agronomic compromise. (2) Outcrossing the AxTE-1 to a number of strains possessing better spinning properties and/or wilt tolerance was begun in 1959.

Development of Acala SJ-1

From one cross made in 1959 (AxTE-1 x New Mexico 2302), a series of very productive F3 progenies were obtained, which constituted an important part of the 1961 nursery (fig. 14). Because the 2302 strain (later released as Acala 1517D in New Mexico) had a tendency for the open cotton to string out (or drop to the ground) before harvest, these F3 progenies were intentionally left in the field until late November so selection pressure could be exerted for this particular trait. It was a fruitful endeavor, as seen by the performance of F4 progenies in 1962.

One superb F4 progeny (row 14) in 1962 was rated excellent in all respects, both in the field ratings and fiber properties. The five best plants from over 20 selections in this progeny were used to provide a bulk of self-pollinated seed to ship to Iguala, Mexico, for an increase plot of one-fortieth of an acre. In 1963, sufficient seed of this 12302 composite was available to plant a 1-acre increase and to be entered in the first replicated yield test. The earliness, yield, and picking efficiency of this 12302 line was outstanding in the 1963 yield test. Furthermore, the F5 progeny rows in the breeding nursery were more than satisfactory in performance measures. They were, however, taller growing than AxTE-1 and did not have the eye appeal that was so striking in the AxTE-1 parent (see fig. 15).

Valleywide yield tests from 1964 to 1967 and numerous quality evaluations by both the USDA laboratories and the textile mills led to the release of this strain of 12302 in 1967, and it was named "Acala SJ-1" (*33*). Acala SJ-1, according to those tests, averaged 8 percent more lint per acre than did Acala 4-42, had a longer fiber, and was slightly coarser (*35*). Approximately 1 week earlier harvest is possible with Acala SJ-1 (fig. 16). This earliness was gained mainly by its ability to retain a much higher percentage of midseason blooms than former Acala varieties grown in the San Joaquin Valley (see fig. 17).

Since the official release of Acala SJ-1 in January 1967, numerous performance trials have been conducted by H. B. Cooper and Dick Bassett, which further verify the research data gained before release (*21*).

Since 1967, two procedures have been changed:

1. Breeder's Seed stock of Acala SJ-1 is being maintained as a "fixed genotype" by storage, and the yearly release is pulled from storage rather than from progeny rows in the nursery.

2. The release of Breeder's Seed is made each year to Foundation Seed Stocks Organization of the University of California, who contract with a single grower to produce White Tag seed. The next two

[9] WALHOOD, V. T. ANNUAL REPORT. In Shafter Station files. 1957. [Typewritten.]

FIGURE 13.—Typical AxTE-1 plant on September 30, 1959.

steps of increase (Purple and Green Tag seed) are handled by the California Planting Cotton Seed Distributors.

These two changes have not hindered the breeding program nor caused any disruption in the delivery of top quality seed of Acala SJ-1 to valley growers.

Other Breeding Developments

Significant genetic and breeding contributions have been made at this station since 1922. Although the applied breeding program commanded the primary attention of the head breeders, new and valuable germ plasm and breeding information has been developed by various investigators.

Beginning in the 1920's, Camp and his associates developed an extra-fine-fibered strain (Acala S-5), which was useful in the breeding program in South Carolina and in several genetic investigations of fiber properties. This strain was called 'Tidewater' after being transferred from Shafter to the coastal islands near Charleston, S.C.

Hubbard, McKeever, and Herbert, as well as Harrison and Rudolph, had a hand in the evaluations for Verticillium wilt tolerance. Selections from several upland varieties were made by the first three workers from 1928 to 1933. Then, from 1934 to 1939, while Harrison and Rudolph were evaluating the progenies from these selections plus other varieties and species, McMichael began to hybridize the adapted Acala strains with the new lines found to possess greater wilt tolerance. One important product of this work was the MxA (Missdel 4 x Acala P18C) combination that became useful in the breeding program during the 1940's and 1950's.

A backcross of MxA to Acala 29 by Harrison gave rise to such experimental strains, as A51, which were used by Turner, G. T. den Hartog, and R. J. Miravalle in the 1950's as an adapted strain with a high degree of wilt tolerance. A51 x THEF (Triple Hybrid-Early Fluff) gave rise to the AxTE-1

FIGURE 14.—Late November view of F_3 progenies (ATE-1 x 2302) 1961.

mentioned previously. A51, 4-42, and Hopi Acala 46 x Early Fluff were all used by Turner and den Hartog as parents crossed to the wilt tolerant Tanguis variety from Peru (*G. barbadense*).

The two sources of extra high fiber strength used in the past 20 years were the triple hybrid lines from North Carolina and the Acala-Hopi material. The original Acala x Hopi Hybrid was made by Peebles and Kearney in Arizona. After Harrison introduced the Acala-Hopi from Arizona, he backcrossed to several Acala strains, from which he developed AHA 6-1, AHA 46-124, and C6-5 (*14*).

New Mexico used the Shafter line AHA 6-1-5-10 to develop the commercial variety, Hopicala. C6-5, because of its high lint percentage together with excellent fiber properties, has been a most useful breeding stock. An official noncommercial release of C6-5 was made in 1960. Harrell, in South Carolina, and others have found it useful. The C6-5 is a parent in several of the present strains being developed by Cooper in the current program at this station. Turner, Sappenfield, and Van Schaik used both the AHA lines and the THEF lines in a breeding program at Brawley. The AHA 46-124 possesses unusually high fiber strength and luster. It has been used in many crosses, but no varietal release has resulted from its use.

Other Hopi material was used by McMichael in hybrids and genetic studies, beginning in the 1940's. In 1953, McMichael found that at least one

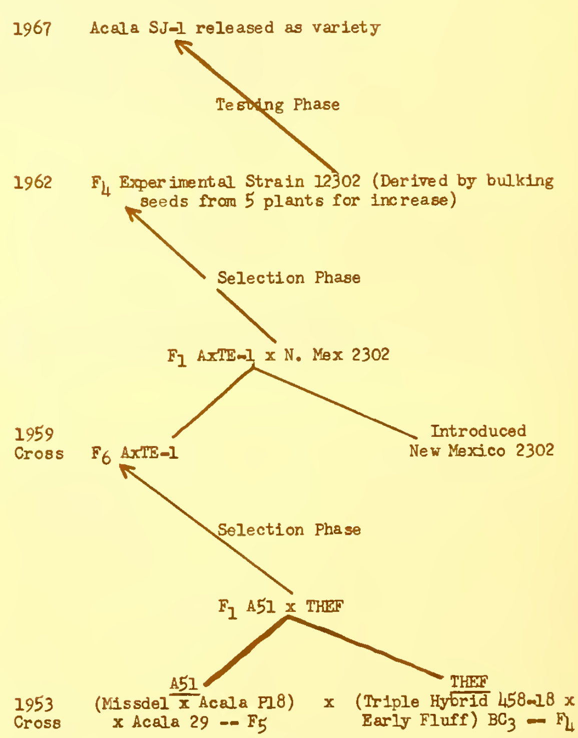

FIGURE 15.—Pedigree of Acala SJ-1.

FIGURE 16.—Acala SJ-1; first increase field (1964).

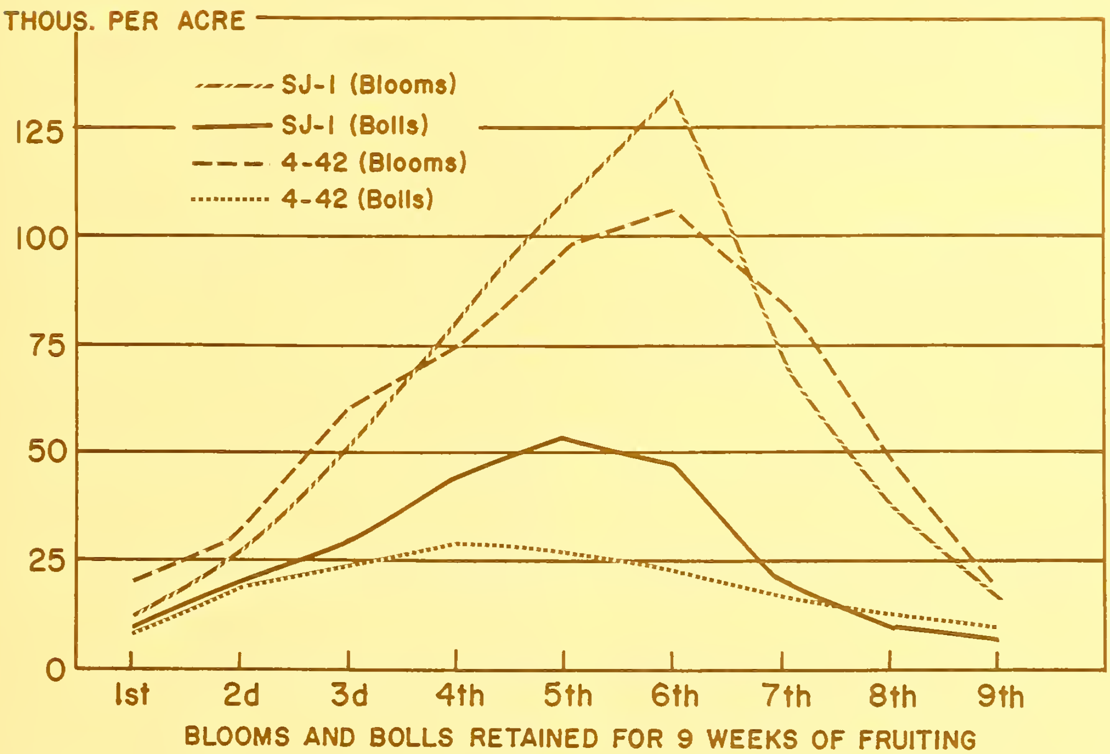

FIGURE 17.—Bloom and boll retention curves for Acala SJ-1 and Acala 4-42.

combination between Hopi and Acala gave rise to a population segregating in the quantity of pigment glands in the leaves and stems (*23*). Intensive screening of seedlings for this trait resulted in McMichael's gland-free seedlings. This material, plus the inheritance pattern determined by McMichael (*24*), has been a most significant development that has become important in many cotton breeding programs. In 1957, Turner and den Hartog began crossing McMichael's nearly glandless lines with adapted Acala strains. Then, Miravalle concentrated much of his time on this project from 1958 to 1961 (*25*). Since 1961, Hyer has developed several agronomic gland-free strains that approach the commercial Acala SJ-1 in performance (*26*). Hyer, in cooperation with entomologists, studied the susceptibility of glandless cotton to insects (*18*). Also, they explored potential mite tolerance among cotton genotypes (*19, 20*).

Nematode-tolerant lines possessing most of the desirable Acala traits have also been developed by Hyer, in cooperation with the nematologists, within recent years. Working with the entomologists, Hyer has also identified the sources of germ plasm that possess a higher level of mite resistance than our commercial varieties.

DISCUSSION

California cotton breeders have, in general, employed the same scientific methods and techniques as used elsewhere in cotton breeding. No doubt the continual scrutiny and pressure from industry groups have been greater than in areas where a one-variety law is not present. All plant breeders have a similar goal in that they constantly strive to develop a better variety than whatever is in current use. The specific traits they strive to improve is a decision each breeder continues to make on a periodic basis.

The breeders who were in charge of the program at the U.S. Cotton Research Station have each faced major problems and diligently explored the ways that breeding could possibly help in their solution. Furthermore, much interdisciplinary research has been conducted to determine how a combination of varietal traits and cultural modifications could provide advancements to the cotton industry. Both USDA and University of California researchers at Shafter and other California sites have played an important role in this program.

From my viewpoint, three eras have transpired for San Joaquin Valley cotton breeding:

1. From 1919 to 1933, the primary attention of the breeder and his associates was to stabilize and maintain an adapted variety of Acala cotton while working with industry and other research personnel toward better cultural practices for irrigated cotton production of a uniform quality.

2. The second era roughly extends from the mid-1930's to the early 1950's. During this period, Verticillium wilt hit the valley cotton, and the development of a wilt-tolerant variety was necessary. Even more critical was the reputation of western-irrigated cotton in the textile markets. It was imperative that Acala strains with better spinning features be developed.

3. The past 20 years have been a period of rapid expansion of mechanized production for the San Joaquin Valley cotton industry. Beginning with the picking machine, the use of heavier farm equipment, and the prohibitive cost of hand labor in cotton production, attention was necessarily forced upon plant, boll, and fiber traits that could withstand the stresses imposed by machinery and chemicals, all the way from land preparation through growing, ginning, and processing. The breeders were "under the gun" for many improvements that could partly or totally be obtained through cultural research studies. Nevertheless, the need for a variety with improved midseason fruit retention was evident to efficiently machine harvest and gin quality cotton before the winter rains began. The need for a good taproot system became more critical due to compaction of soil by heavy equipment and the need to continue selecting for higher levels of fiber quality because all machines (from the harvester through the textile mill processes) diminish the inherent properties of fiber. These features were (and continue to be) goals of the San Joaquin Valley breeding program.

Progress made for yield and fiber quality in this valley is summarized in charts (fig. 18). On the surface, this may seem unusual — that both yield and quality gains occurred while acreage increased — but let us put this in proper perspective. The past 50 years was the beginning period of cotton production for this virgin land compared to the Southern and Southeastern States where cotton production and breeding had been pursued for a century previous.

Each generation of breeders has built upon the discoveries of its predecessors. A much wider base of germ plasm has been available in recent years, and much has been learned regarding ecological adaptation. It is my opinion that much greater progress can be realized in future varieties. My experiences with breeding materials in Georgia and California led me to the conviction that the diverse ecological regions of cotton production in the United States have influenced the breeding of distinct genotypes that provide the genetic base necessary for breeding programs. Western region breeders have attained high levels of fiber quality in current varieties, but they stand to gain in yield and production efficiency from hybridizing their adapted varieties with rainbelt genotypes. Conversely, Southern State breeders have developed breeding

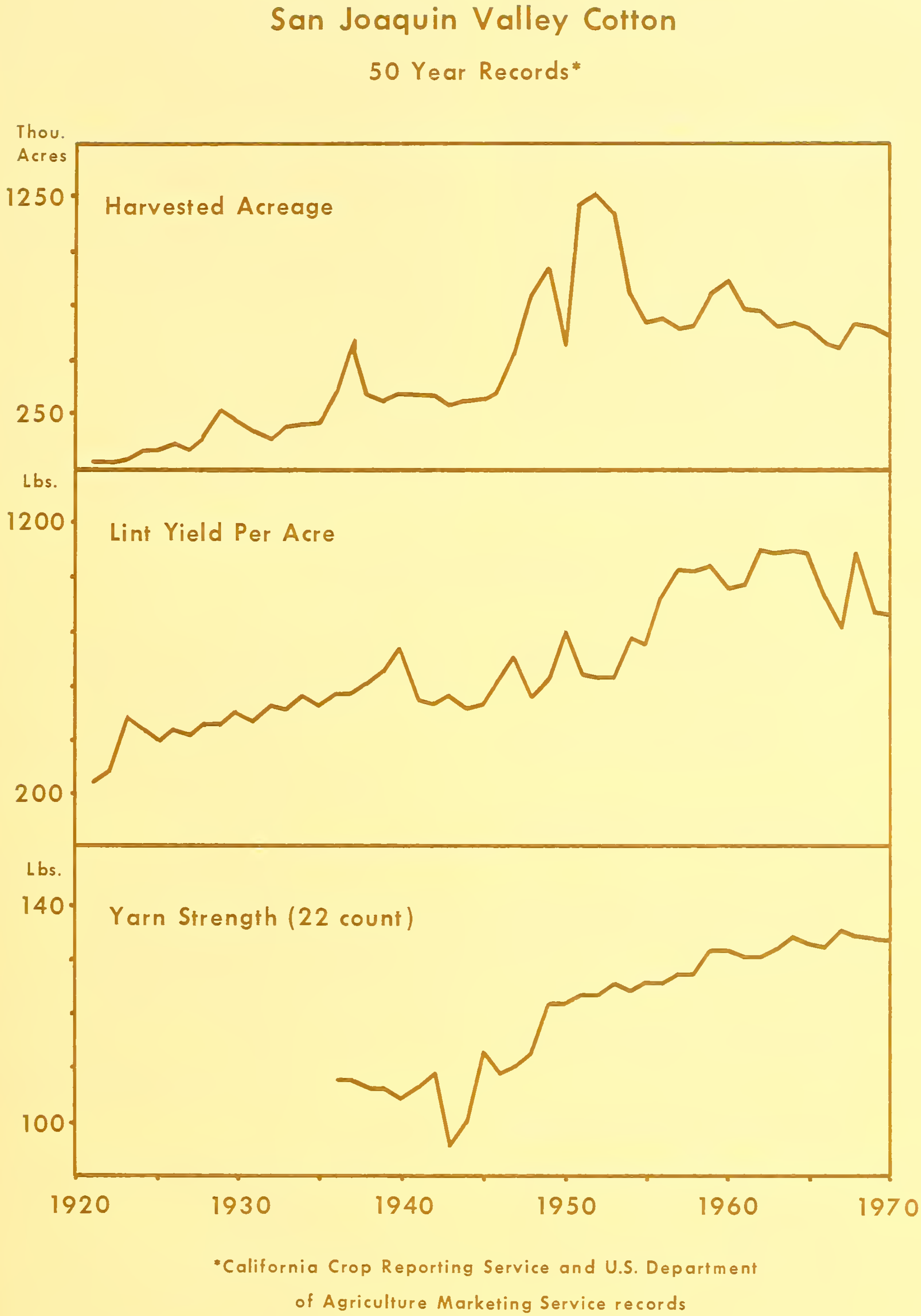

FIGURE 18.—San Joaquin Valley cotton record—acres, yield, and quality (1921-70).

materials over many years that have wide adaptation, earlier maturity, are extremely productive, and could gain considerable quality from intergression of western genotypes.

Cotton breeding is an endeavor where both art and science are employed. Many traits, that contribute to final yield and production efficiency, such as stalk erectness, disease tolerance, and seedling vigor, call for the keen eye and judgment of the breeder. Far more objective evaluations of fiber qualities have become a routine part of breeding since the development of modern instruments of the past 30 years. Techniques have been greatly improved for the conduct of field and laboratory studies. Further refinement of methods and techniques will no doubt aid breeders in making more rapid genetic advances. Even with the best possible choice of germ plasm, methods, and techniques, the applied breeder has to live with (and perpetuate) compromises. His most recent variety will continually show need for improvement in one or more traits.

Changes are a continuing reality in agriculture and in the industries that consume farm crops. A cotton breeder must be alert to new trends in culture, climate, and consumer needs and remain objective with the germ plasm and resources he has at his disposal to attain specific goals. Furthermore, he must use practical judgment as to how many problems and how wide an area to extend himself in developing new and better varieties.

The breeders and associated cotton research personnel that have been involved in the San Joaquin Valley cotton program over the past 50 years have been fortunate in several respects; namely, (1) the pioneering of growers in the 1920's who had few preconceived ideas of cotton production, (2) the need for unity was prevalent with all California agricultural commodities, and (3) the unusually favorable climate and soils for cotton production.

In retrospect, the author can see that the San Joaquin Valley cotton program has advanced from the horsedrawn plow and hand hoe to a modern mechanized industry employing high-powered equipment and agricultural chemical, which require sound management and precision at all stages of cotton research, production, and marketing.

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